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FERMILAB-Conf-96/105

Detector Possibilties for a $\mu^+\mu^-$ Collider

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May 1996

Published Proceedings of the *3rd International Conference Sponsored by UCLA on Physics Potential and Development of* $\mu^+\mu^- Colliders, San Francisco, California, December 13-15, 1995$

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

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l. INTRODUCTION

During the past two decades accelerators have advanced much too fast in energies and luminosities for detectors to cope with. Nevertheless we High Energy Physicists had to come up with some detector design and did lot of good physics using them. The CDF can be given as an excellent example. Although the CDF was designed for a luminosity of $10^{30}cm^{-2}sec^{-1}$, it ran at luminosities around 2 x lO^{32} before the shutdown in March 1996 .The detector has to go through a major upgrade to run when the Main Injector come on with an expected luminosity of 2 x 10^{32}. This requires completely new tracking systems, and some of the calorimeter systems need to be replaced. This is a challenging work, and it may cost more than the original cost of the detector. At this time we do not have well proven technologies to build tracking and calorimetry for the LHC to run at luminosities of $10^{34}cm^{-2}$ sec^{-1} and beyond. We need radiation hard silicon pixel and silicon strip detectors. Gaseous chambers to run at such luminosities with hundreds of tracks for each event is not feasible at this time. People who are hoping that the microstrip gas chambers (MSGC) will work long enough time at such luminosities may be disappointed.

The proposed $\mu^+\mu^-$ collider will have long bunch crossing times as compared with high luminosity hadron colliders, but the background that will be produced by the circulating muons (see Nikolai Mokhov's computer simulations,[l] in this issue). Electromagnetic showers that is produced by the decay electrons (average energy is 600-700 GeV for the 2 on 2 TeV option) will result in gammas and intensive showers away and within a detector volume. This and the neutron background could make the machine background very large unless proper absorber materials are placed around and within the detector to reduce the background in the detector to produce physics. Considering the expected large background, a $\mu^+\mu^-$ collider detector can be as challenging as the LHC detectors (CMS and ATLAS).

The choice of a $\mu^+\mu^-$ detector may be between a reasonably compact one and a very large one (V Polychronakos et al. [2]) that has been proposed during these series of conferences. Cost of the proposed large detector will be too high to afford, and may not do better physics than a modified CDF detector that is proposed here. The CDF with the upgrades for Run II can be a suitable detector for the $\mu^+\mu^-$ collider but due to expected radiation damage after an integrated luminosity of 5 fb^{-l} barn, we may need to build a new detector.

2. PROPOSED $\mu^+\mu^-$ DETECTOR

A schematic view of a modified CDF is shown in Fig. 1. The modification is done to help reduce the expected background from the machine and to enrich the physics capability by adding a particle identifier system. Also more iron is added to the muon detector and the hadron calorimeter system due to the experience gained using the present CDF.

I believe that GaAs pixel vertex tracker and GaAs strip tracker for the innermost tracking systems are most likely the technologies to be matured by the time they are needed. GaAs is going to be a good tracker due to their high radiation resistivity, and for their relative insensitivity to the neutron background since they produce very small recoil energy by a few MeV (in the average) background neutrons. The recoil energy can be shown to be around few keV in the GaAs, and more than 70 percent of the recoil energy goes to phonon excitation not to the ionization. Few keV energy deposition in the GaAs can produce electron pulse that would be in the noise. Gammas can produce Compton electrons and e^+e^- pair production in the GaAs layers that needs to be studied. Mokhov's calculations indicate that the Gamma-ray background is an order of magnitude less than the neutron background, and it is possible that most of these conversions can be removed by the track reconstruction. Pixel size of 1 mm^2 may be required for the GaAs vertex tracker, and high resolution short strips may also be needed. Both of these would require bump bonding technology.

High resolution vertex TPC (Time Projection Chamber) may do well as the outer tracker. The TPC has to run with a nonhydrocarbon gas mixture for it to be insensitive to the neutron background. A CO_2 combination may be recommended. Small addition of CF4 can reduce the drift time of the electrons considerably (A CO_2 is a slow gas mixture).

I am less confident about the particle ID of any type, but if the background allows adding a barrel and forward DISC-DIRC (directional Cerenkov) detectors can enhance the physics capability of the detector. T. Kamae reported[3] some Monte Carlo and test results at UCLA that promising when the Cerenkov photons are guided by optical fibers to VLPCs (Visible Light Photon Counters)[4]. The scheme is shown in Fig. 2. The technology is new and needs further study.

The electromagnetic and hadronic calorimeters can be made using scintillating tiles which are read out through wave shifter fibers. The CMS group of Fermilab has been developing the tile technique for the hadronic calorimeter. The same technique can be used for the EM calorimeter of the $\mu^+\mu^-$ collider also. Lead-tungstate crystals with Hybrid-APD (HAPD) is another candidate for the EM calorimeter. One concern about the HAPDs is their being susceptible to radiation damage. Muon and toroidal draft chambers are matured technologies, thus we will not go into details about them here.

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